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Forest Inventory and Management-Based Visual Preference Models of Southern Pine Stands

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ABSTRACT. Statistical models explaining students' ratings of photographs of within-stand forest scenes were constructed for 99 forest inventory plots in east Texas pine and oak-pine forest types. Models with parameters that are sensitive to visual preference yet compatible with forest management and timber inventories are presented. The models suggest that the density of sawtimber-sized trees and the proportion of visual penetration are positively associated with scenic beauty. Foliage, twig, and small stem screening, and the density of small-diameter trees are negatively associated with scenic beauty. Results generally concur with other visual preference studies of within-stand forest scenes. Such models and associated parameter estimates can be used to objectively assess within-stand forest scenes and to routinely monitor scenic beauty of southern pine forest resources. Unlike similar scenic beauty studies, the limited amount of downed wood encountered was positively associated with scenic beauty. Also suggested is a decline in perceived scenic beauty during the summer season (May-October) coincident with sampling from northeast to southwest sections of east Texas. FOR. SCI. 34(4):846–863.

ADDITIONAL KEY WORDS: Scenic beauty estimation, scenic quality, multiresource forest inventories, vegetative screening, within-season change, regional change.

THE AESTHETIC QUALITIES OF FORESTS have long been valued as important forest "products." Studies in the northeastern United States (e.g., Birch 1983) have indicated that one of four nonindustrial private forest landowners lists recreational use and aesthetic enjoyment as primary reasons for owning forestland. Forest landowners have expressed preferences for stands with large, enclosed spaces and spaces created by thinning well-stocked stands (Brush 1979). General public concern for aesthetics is reflected in federal legislation, such as the Forest and Rangeland Renewable Resources Planning Act of 1974 and the National Forest Management Act of 1976. These measures specifically list aesthetics among those factors to be considered in comprehensive assessments for planning and management of the nation's forest resources.

Models based on traditional forest inventory data (e.g., basal area, number of live trees, cubic foot volume) are being used increasingly to address regional forest planning and management issues, including wildlife habitat, water quality, and other multiresource concerns (Joyce et al. 1983).

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In this regard, attempts to link public aesthetic perception models with forest inventory parameters become critical. There is also a growing need to suggest forest management that more directly affects noncommodity values. Needed are models with parameters that can be measured objectively over extensive areas and that are sensitive to manageable forest characteristics that affect aesthetic perceptions. Intuitive models, i.e., models with straightforward silvicultural inferences and parameters known or thought to be directly associated with aesthetic perception, are believed to be more widely applicable and acceptable than those that maximize statistical associations.

The Scenic Beauty Estimation (SBE) procedure (Daniel and Boster 1976) has been used extensively to measure the visual preference for forested environments. Previous research in ponderosa pine forest type of southwestern United States has established that herbage and large trees contribute to perceived scenic beauty, while small and intermediate-sized trees and downed wood (primarily slash) detract from perceived scenic beauty (Brown and Daniel 1984, Schroeder and Brown 1983). More recent studies in oak-hickory forest type in Virginia (Vodak and others 1985) and loblolly-shortleaf pine forest type on the North Carolina Piedmont (Buhyoff et al. 1986) have yielded similar results. These studies have shown that open, or parklike, conditions, and relatively large trees intermixed with other sizes, improves perceived scenic beauty. Small-diameter trees and dense understory vegetation reduces perceived scenic beauty. Downed wood also reduces perceived scenic beauty. However, it is uncertain whether these relationships can be applied to forests in other areas.

The purpose of this study is to develop intuitive models of perceived scenic beauty using manageable and measurable characteristics of forests within the constraints of a forest inventory sample design. Intuitive models for a variety of forest conditions can provide a basis for managing timber stands to minimize aesthetic degradation or enhance scenic beauty. The models also can provide mechanisms for systematic consideration of visual preferences in forest resource assessment based on extensive area, plot-based forest inventory data.

Another purpose of this study is to help identify the need for measures that are sensitive to scenic beauty and compatible with extensive-area forest inventories. Parameters selected or added were designed to help identify causal relationships between scenic beauty estimates and east Texas pine and oak-pine stands. These include the density of large and small trees, the proportion of open or parklike conditions, the proportion of screening by tree boles, foliage and twigs, and other obstructions, and the amount of downed wood. Since the latter parameters are not estimated routinely from southern timber inventory measurements, models were developed and comparisons were made between models with and without these parameters.

METHODS

Field crews from the Southern Forest Experiment Station, Forest Inventory and Analysis Unit (FIA), used 35mm cameras to photograph 120 forested plots in Harrison, Nacogdoches, Houston, Sabine, and St. Augustine counties of east Texas. Counties were selected from 1974 records of permanent sample plots that indicated abundant loblolly-shortleaf pine forest type. A range of forest management conditions was built into the sample by including counties with National Forest land as well as forested land in forest industry and other private ownership. Plots within counties were located systematically at approximately 3-mile intervals. To represent the range of pine types, plots were chosen if one or more pine trees were present in the canopy. Constraints of training, equipment needs, and the working schedule of survey crews also were taken into account in selecting plots.

Potential bias in scenic beauty assessment due to seasonal color change (Buhyoff and Wellman 1980) was limited by restricting the photography to the 1985 summer period (May to October in east Texas). Cameras used were aperture-preferred (i.e., automatic shutter speed) and pocket-sized. To maximize depth of field, an F-stop of 8 or above was used. The ASA 400 color slide film used was push-processed to ASA 800 to compensate for low-light conditions in closed-canopy stands. At every plot an identification photo was taken, as well as 5 eye-level photographs: one from each of the first 5 of the 10 sample points within the plot. The focus of scenes was 30 feet to infinity. Photo direction was determined by a random schedule of compass points. Obstructions that blocked the immediate view were moved only as needed to take photographs. Otherwise, photo-sampling and processing followed that of Buhyoff et al. (1986).

Three survey crews, each working independently and at different plots, photographed scenes as an adjunct to normal FIA inventory measures. The "standard" timber inventory data dervied from FIA measures (e.g., tree basal area, species distribution, cubic foot volume, forest type) were based on a 10-point sample to assess the forest resource for each 1-ac plot (FIA 1985a). Other standard FIA indices associated with nontimber resources assessment also were recorded. These indices included evidence of burning, human use, and livestock use; proximity to water, roads, urban areas, and agricultural areas; relative amount of slash; forest size; slope; and aspect (FIA 1985a, 1985b). Several other rountinely archived parameters of survey data, defined here as "study-based parameters," were examined in this report. Study-based parameters were the Julian date when measurements were taken and the approximate location of plots by longitude and latitude.

In addition, "nonstandard" parameters hypothesized to be associated with visual preferences were estimated by the survey crews: vegetative screening and downed wood volume. Estimates of vegetative screening and downed wood volume were collected for the first five points along two 50-ft transects: one in the direction of the photo, and one in the opposite direction. Screening by trees 5 in. or greater in diameter (at breast height), screening by foliage, twigs, and stems less than 5 in. in diameter, visual penetration (absence of screening), and other screening (physical obstructions such as bare soil on embankments) were estimated with a screenometer (a scaling device to quantify screening). Methods followed Rudis (1985) for five points per plot and two views per point. Measurements for downed wood 1 ft long × 1 in. diameter or larger in 2-in. diameter classes were taken along the transects, following procedures outlined by Brown (1974).

Slides were evaluated for photographic quality and catalogued by plot, point, and transect. Of the 120 plots selected, some were not included in the scenic beauty estimation (SBE) procedure because the identification photo was illegible or stands did not contain at least 25% softwood stocking (21 plots). For the remaining 99 plots, slides were eliminated if under- or overexposed, or contained manmade features (e.g., a distant house visible in the photograph). Except for one plot with three slides and seven plots with five slides, four slides were used to assess scenic beauty for each plot. Approximate locations of the 99 plots are illustrated by county in Figure 1. The frequency of FIA forest cover types were as follows: 78 loblolly-shortleaf

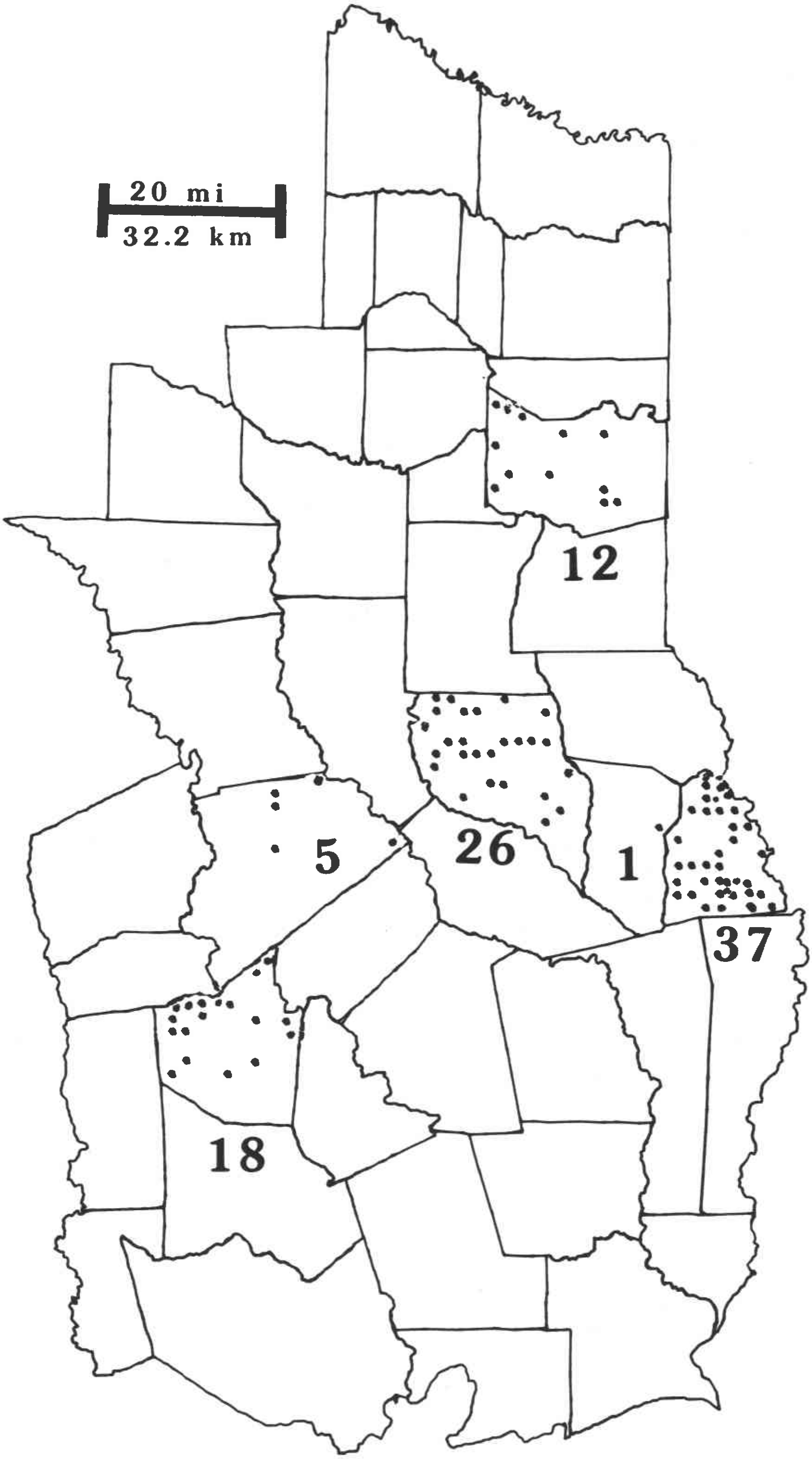

FIGURE 1. Approximate plot locations surveyed in east Texas for scenic beauty. County coded by sample size: 37 = Sabine, 26 = Nacogdoches, 18 = Walker, 12 = Harrison, 5 = Houston, 1 = San Augustine.

pine, 18 oak-pine, and 3 longleaf-slash pine. Terrain was flat to gently rolling, with slopes averaging 6% (range 1 to 22%).

The SBE procedure was used to assess the scenic beauty of slides (Daniel and Boster 1976). Slides were judged by undergraduate students enrolled in a campus-wide survey course at Texas A & M University. Previous research was shown that students' visual preferences for natural scenes are representative of the general public (Schroeder and Daniel 1981, Zube et al. 1974). This procedure also reduced costs, a major consideration in the practical application of visual preference measurements.

In spring 1986, 5 class sections (approximately 35 students each) evaluated 403 slides. Students viewed a set of warmup slides, then rated 100 additional slides on a 10-point scale where 10 = highest scenic beauty. Each slide was shown on the screen for 5 sec. For logistical reasons, not all slides were rated by each student. Instead, 26 "baseline" slides were systematically interspersed through each tray of 100 slides shown to each class section so that a common reference point for SBE scores could be obtained. SBE scores were adjusted proportionately to take into account rater-to-rater differences in mean scores across slides. SBE scores were averaged by plot and compared with other plot-level parameter estimates.

An intraclass reliability coefficient was calculated for each of the five class sections that rated slides. The reliability coefficient estimates the proportion of the total variance among scores due to slide-to-slide variance, as opposed to the proportion due to differences among raters (Tinsley and Weiss 1975). Because SBE scores were already adjusted to account for differences among raters, the intraclass reliability coefficient was calculated excluding variance among raters.

Simple correlation coefficients (r) and least squares multiple regression with plot-level SBE values as the dependent variable were used to assess the significance of parameters in accounting for variation in perceived scenic beauty. To reduce the influence of individual observations on model forms selected, the PRESS-R**2 was also used in model selection (see Draper and Smith 1981, p. 325). Parameters selected for regression equations were those that had significant correlations with plot-level SBE values ($P|r|<0.05$). To avoid inclusion of highly intercorrelated parameters, all coefficients (bi's) of the final model parameters were required to have a t-value probability ($P>|t|$) of 0.05 or less.

Because many of the parameters were intercorrelated, several models did a good job of accounting for statistical variance in SBE values; i.e., high coefficents of determination (R**2). Stepwise regression was used initially as a guide for selecting parameters. Other parameters tested for inclusion were chosen to provide insights into silvicultural treatments that were thought to affect visual preferences. Parameters selected for the final models were those that minimized intercorrelations [condition indices (Weisberg 1980, p. 178)] for a given R**2 value.

Assumptions associated with regression—i.e., that all parameters and error terms in the models were normally distributed, that parameter variance was homogeneous, that a linear association existed between parameters and the dependent variable, and that the presence of outliers did not affect results—were tested by visual inspection of normal probability plots, testing of several statistical transformations, and visual inspection of residual plots. No cases were dropped because of unacceptable outliers. The logarithmic transformation was used for downed wood volume. For a few other parameters, transformations increased the homogeneity of variance. Because of the desire to preserve ease of interpretation, and because other transformations did not add greatly to the explained variance (less than a 0.03 change in R**2), only straightforward parameters and linear models with additive parameters (no interaction terms) are presented. In contrast to the nonlinear and interactive forms suggested by others (Buhyoff et al. 1986, Hull et al. 1987), our approach was to explore the significance of straightforward parameters and models. Omission of transformed parameters and interaction terms should contribute to both the generality and the understanding of the models (Schroeder and Brown 1983).

To determine the utility of nonstandard but visually important parameters in forest surveys (i.e., screening and downed wood estimates), models were developed for (I) standard forest survey parameters and (II) standard and nonstandard parameters. Models that include study based parameters are also presented to assess regional and temporal variation in scenic beauty specific to the plots examined.

Models were selected to increase the intuitive understanding of the relationship between readily and objectively measured stand characteristics and visual preferences. Predictors that significantly correlated with plot-level SBE values were analyzed using principal components analysis with varimax rotation (SAS Institute, Inc. 1985). Principal components analysis was used to suggest underlying associations among predictors. Models based on principal components help assess their relative importance to variance in scenic beauty estimation.

RESULTS

In this study, individual slide SBE values range from -116.19 to $+106.07$, while average plot-level SBE values range from -70 to $+79$, with a mean of -1.30 and a standard deviation of 30.8. As a group, the most preferred slides exhibit a relatively large amount of visual penetration into the scene and a relatively large number of large-diameter trees. By contrast, the least preferred slides were those with little visual penetration and with a large amount of foliage and small-diameter trees.

The mean, standard deviation, and range for values of selected parameters significantly associated with plot-level SBE values ($P|r| < 0.05$) or considered to be important in visual preference studies are listed in Table 1. Additional parameters considered are presented elsewhere (Gramann et al. 1986). Correlations for selected parameters are presented in Table 2.

Intraclass reliability coefficients for the baseline-adjusted ratings ranged from 0.852 to 0.918, with an average for the five groups of 0.900. In addition, an intergroup reliability coefficient was calculated based on the SBE scores for the 26 common baseline slides rated by all five groups. The Pearson product-moment correlations ranged from 0.801 to 0.925, with an average correlation of 0.881 for all ten possible pairwise comparisons. This suggests substantial agreement among groups on the scenic beauty of the 26 baseline slides and supports the computation of regression models based on the combined ratings of all five groups of judges.

The objectives in model-building are to maximize explained variance while providing intuitive models that relate forest inventory parameters (standard and nonstandard) and study-based parameters to visual preferences. Table 3 presents the statistical models with related regression statistics. Table 4 shows the correlation matrix for the parameters used in these models.

Models with Standard Parameters

Model 1 (Table 3) implies that increasing the density of sawtimber (SMSTT) and hardwood poletimber (PLHWT) trees increases scenic beauty, while increasing the density of smaller trees (SAPT) decreases scenic beauty. Model 4 is similar except that the equation takes into account the variation in sampling date (JDATE), and uses basal area of hardwoods and softwoods instead of density measures.

Models with Standard and Nonstandard Parameters

Model 2 implies that an increase in visual penetration (VSPN), an increase in small sawtimber-sized tree density (SMSTT), and an increase in downed wood 4 in. in diameter (DW4) improves scenic beauty. Model 3, based on parameters without downed wood volume, suggests increasing gross cubic foot volume (GCFLV) and increasing visual penetration (VSPN) improves scenic beauty.

Models with Study-based Parameters

With the addition of Julian date (JDATE), Models 5 and 6 imply that forests in late summer have less scenic beauty than those in early summer, that increasing visual penetration (VSPN), or decreasing foliage, twig, and shrub screening (FTWG), increasing sawtimber-sized trees (SMSTSWT, SMSTT) and decreasing small diameter-weighted live tree density (LVACSW) increases scenic beauty. Model 5, based on parameters without downed wood volume, provides slightly better R**2 values than Model 6 with the inclusion of LGSTT, FTWG, and SMSTSWT instead of DW4, VSPN, and SMSTT. Intercorrelations among parameters are slightly higher with Model 5, however. Model 7 includes longitude (LONG), suggesting that scenic beauty decreases from east and west, that foliage, twig, and small stem screening (FTWG) decreases scenic beauty, and that softwood sawtimber density (SMSTSWT) and 4-in. diameter downed wood density increases scenic beauty.

Standardized beta coefficients, indices of the relative contribution of parameters to the prediction model, are greatest for foliage, twig, and small stem screening in Models 5 and 7 and for visual penetration in Models 2 and 6. In Models 1 and 4, R**2 values are considerably less than equivalent models where nonstandard parameters are used. These findings suggest that use of visual penetration or screening measures would improve the prediction of scenic beauty in southern pine forest surveys.

The significance of Julian date in Models 4, 5, and 6 is apparent from the magnitude of the standardized beta coefficents. Plots sampled in late summer have lower scenic beauty values than those sampled in early summer.

Inclusion of Model 7 with longitude instead of Julian date is provided as a basis for discussion. One can argue that regional differences, indexed by the longitude parameter, are potential causal mechanisms for the association with scenic beauty rather than within-season change. Julian date is preferred over longitude in model building as the former is not significantly correlated ($P|r|>0.05$) with any of the other parameters considered; correlations between Julian date and visual penetration, screening, stand age, downed wood volume, site productivity, sawtimber density, and basal area

TABLE 1. Descriptive statistics for selected parameters, 99 east Texas forest survey plots.

Parameter	Mean	Standard deviation	Minimum	Maximum	Description
FTWG	68.6	22	4	100	percent screening by foliage, twigs, and stems <5 in. dbh
VSPN	19.5	19	0	89	percent visual penetration (or absence of screening by FTWG, OTHSCR, and TRBOLE)
TRBOLE	11.7	8	0	36	percent screening by stems >=5 in. dbh
OTHSCR	0.2	1	0	10	percent screening by bare soil
DWV	105.6	110	0	415	cu ft/ac of downed wood >=1.0 in. dbh
LDWV	4.0	2	0	6	log (1 + DWV)
DW4	2.1	2	0	11	number/acre of downed wood 4 in. (3.0–4.9) diameter
GCFLV	1,895.1	1,159	0	5,836	cu ft/ac of all live trees >=5.0 in. dbh
SMSTT	39.5	26	0	134	number/acre of small sawtimber-sized trees (11.0–20.9 in. dbh)
SMSTSWT	32.3	25	0	102	number/acre of small softwood sawtimber (11.0–20.9 in. dbh)
LGSTT	1.7	3	0	11	number/acre of large diameter sawtimber-sized trees (>=21.0 in. dbh)
SAPT	537.1	519	0	2,934	number/acre of sapling-sized trees (1.0–4.9 in. dbh)
SAPSWT	195.4	416	0	2,934	number/acre of sapling-sized softwood trees (1.0–4.9 in. dbh)
PLHWT	40.4	40	0	168	number/acre of poletimber-sized hardwood trees (5.0–10.9 in. dbh)
BALV	98.7	39	0	230	ft^2/ac, basal area of live trees >=1.0 in. dbh
BALVSW	68.3	34	0	173	ft^2/ac, basal area of live softwood trees >=1.0 in. dbh

TABLE 1. Continued.

Parameter	Mean	Standard deviation	Minimum	Maximum	Description
BALVHW	30.5	22	0	84	ft^2/ac, basal area of live hardwood trees >=1.0 in. dbh
LVAC	688.3	521	0	3,032	number/acre, live trees >=1.0 in. dbh
LVACSW	298.5	421	0	2,997	number/acre live softwood trees >=1.0 in. dbh
SIZEC[a]	2.6	1	1	3	plurality size class of merchantable trees
SVC[b]	2.4	1	1	3	board foot volume class of merchantable trees
SITEC	125.2	34	68	195	$ft^3/ac/yr$, site productivity class
AGE	36.0	17	3	92	average age (yr) of the dominant trees in the stand
AVGD	4.7	2	0	13	average dbh of live trees >=1.0 in.
SLASH	39.5	90	0	415	ft^3/ac downed wood on plots with slash
JDATE	218.8	40	136	304	Julian date
LONG	94.5	1	94	96	degrees long.
LAT	31.5	1	31	33	degrees lat.

[a] 1 = sapling or seedling, 2 = poletimber, 3 = sawtimber.
[b] 1 = less than 1500 bd ft, 2 = 1500 to less than 5000 bd ft, 3 = 5000 bd ft or more.

measures are particularly low ($P|r|>0.50$). Longitude (i.e., westerly location) is significantly associated ($P|r|<0.05$) with lower site productivity ($r = -0.30$), greater visual penetration, less screening, and fewer hardwoods younger stand ages ($r = -0.20$), (Table 4). By using longitude (Model 7) (vs. Julian date in Model 5), the statistical and logical influence of other parameters are obscured.

Examination of a subset of the data provide additional evidence that the association between scenic beauty and Julian date is not spurious. In Sabine County (sample size = 37), sampling occurred between mid-June and end of September. Least squares regression results yielded models where coefficients for Julian date were the third most significant contributor ($P|t|<0.05$) to within-county models and where coefficients for longitude parameters were not signficant ($P|t|>0.60$).

Principal Components

Principal components analysis yields seven factors with eigenvalues of 1.0 or greater for parameters correlated with scenic beauty estimates. These factors account for 81% of the variance in scores on parameters correlated with SBE values. Table 5 lists eigenvalues for each principal component (factor), along with the percent of variance that it accounts for.

TABLE 2. Correlations with plot-level scenic beauty estimates for selected parameters.[a]

Parameter	*r*	Parameter	*r*
FTWG	−0.51	LVAC	−0.30
GCFLV	0.44	LVACSW	−0.30
VSPN	0.42	DW4	0.29
SMSTT	0.41	AGE	0.29
TRBOLE	0.40	LAT	0.26
SMSTSWT	0.37	LONG	−0.25
SIZEC	0.35	SITEC	0.24
AVGD	0.35	BALVSW	0.24
JDATE	−0.34	PLHWT	0.23
BALV	0.33	BALVHW	0.21
SVC	0.33	LGSTT	0.21
SAPT	−0.33	DWV	0.18
SAPSWT	−0.32	SLASH	0.09
LDWV	0.31	OTHSCR	−0.02

[a] $P(|r| > 0.16) = .10$, $P(|r| > 0.20) = 0.05$, $P(|r| > 0.26) = 0.01$, $P(|r| > 0.39) = 0.001$.

Primary loadings are used to interpret and name each factor. Factor 1 is labeled "Small Sawtimber Density." Parameters loading on this factor (i.e., basal area and density of sawtimber-sized trees) represent the relative abundance of sawtimber-sized trees. Since most stands examined are dominated by softwoods, this factor can also be interpreted as generally representing softwoods.

Factor 2 is labeled "Sapling Density." Parameters representing the number of sapling-sized trees and the number of trees per acre are loaded on this factor. Factor 3 is labeled "Poletimber Density." All hardwood-related parameters are loaded on this factor, so it also may represent the relative contribution of hardwoods to the data set. Factor 4 is labeled "Visual Penetration." The two parameters representing foliage, twig, and small stem screening and visual penetration into the forest scene are loaded onto this factor. Factor 6 is labeled "Downed Wood Volume." Parameters and values associated with older stands (i.e., higher average diameter of trees and stand age) are also loaded on this factor, so this factor may also represent stand maturity. Factor 7 is labeled "Large Sawtimber Density." Stand age and site productivity class are also positively associated with this factor.

Study-based parameters are loaded onto Factor 5. Julian date (JDATE) is correlated with latitude (LAT, $r = -0.53$) and with longitude (LONG, $r = 0.38$). Sampling occurred early in the season in the northern and eastern part of the study area and later in the season for the southern and western part of the study area. On average, plots sampled in early summer have higher scenic beauty than plots sampled in late summer.

We propose that this factor represents a within-season effect ("late in the season"), although we cannot discount the existence of a latitude or longitude gradient. One might logically consider that scenic sites are clustered geographically, as they may possess similar stand structure or unmeasured environmental attributes that make them preferred. The sequence of sampling by field crews could have inadvertently sampled scenic plots early in the season, and less scenic sites late in the season. However, interviews with field cruisers regarding the sequence of plots selected for sampling suggested no obvious relationship to the scenic beauty of stands. Furthermore, most plots sampled were at least 3 miles from one another.

TABLE 3. Models that predict scenic beauty from plot-level parameters.

Model number	Parameter subset Regression statistics (R**2, R**2-adj, PRESS-R**2, condition index)		Coefficient	Beta	$P > \|t\|$
(1) With standard parameters.					
	(0.27, 0.24, 0.21, 1.29)	SMSTT	0.38	0.33	0.0005
		SAPT	−0.02	−0.27	0.0036
		PLHWT	0.14	0.18	0.0462
		(Constant)	−13.56	0.00	0.0370
(2,3) With standard and nonstandard parameters.					
(2)	(0.36, 0.34, 0.30, 1.22)	VSPN	0.60	0.38	0.0001
		SMSTT	0.39	0.34	0.0001
		DW4	3.01	0.22	0.0108
		(Constant)	−34.88	0.00	0.0001
(3)	(0.34, 0.33, 0.30, 1.07)	GCFLV	0.01	0.41	0.0001
		VSPN	0.63	0.39	0.0001
		(Constant)	−34.12	0.00	0.0001
(4) With standard and study-based parameters.					
	(0.40, 0.37, 0.34, 1.26)	SAPT	−0.03	−0.43	0.0001
		JDATE	−0.31	−0.40	0.0001
		BALVHW	0.37	0.27	0.0013
		BALVSW	0.24	0.27	0.0012
		(Constant)	51.84	0.00	0.0014
(5,6,7) With standard, nonstandard, and study-based parameters.					
(5)	(0.48, 0.46, 0.42, 1.49)	FTWG	−0.55	−0.39	0.0001
		JDATE	−0.27	−0.35	0.0001
		SMSTSWT	0.26	0.21	0.0078
		LVACSW	−0.01	−0.17	0.0400
		LGSTT	2.10	0.17	0.0268
		(Constant)	87.26	0.00	0.0001
(6)	(0.48, 0.45, 0.40, 1.44)	VSPN	0.52	0.32	0.0001
		JDATE	−0.23	−0.30	0.0001
		SMSTT	0.32	0.27	0.0008
		DW4	2.92	0.21	0.0070
		LVACSW	−0.02	−0.21	0.0089
		(Constant)	25.66	0.00	0.0859
(7)	(0.47, 0.45, 0.41, 1.46)	FTWG	−0.73	−0.52	0.0001
		LONG	−14.80	−0.33	0.0001
		SMSTSWT	0.23	0.19	0.0183
		DW4	2.47	0.18	0.0215
		(Constant)	1435.74	0.00	0.0001

The decline in scenic beauty over the study period (mid-May to end of October) is believed to be due to a change in the ground surface texture and complexity of scenes. Between-season changes have been suggested by Buhyoff and Wellman (1980). The psychophysical literature (Ulrich 1983) has suggested that scenic beauty changes occur with changes in ground surface texture and complexity of scenes. Temperate forest vegetation undergoes a maturation process in the course of the summer, resulting in changes to the relative greenness and texture of leaves. The ground vegetation (woodland herbs, grasses, fallen leaves) undergoes similar within-season changes, which suggests changes to the ground surface texture and overall complexity of scenes depicted.

We cannot rule out the probability that there exists a regional gradient coincident with sampling date. Aspect for the more rugged terrain and precipitation-limited vegetation of north-central Arizona has been suggested as contributing to environmental differences in scenic beauty (Brown and Daniel 1984). However, terrain and precipitation in the east Texas study area are relatively uniform. Slight undulations of terrain or soil moisture conditions (not measured in this study) could affect the vegetation and appearance of scenes. Further study of regional differences is warranted, as documentation of the existence of a spatial gradient in near-scene forest views may alter aesthetic management priorities in forests toward regions with the greatest scenic potential.

Standardized principal component score coefficients are computed for each parameter. The results are summed across each factor to create composite variables, one for each factor. The principal component models (Table 6) mirror the findings from the other equations. Scenic beauty can be increased by increasing visual penetration (decreasing foliage, twig, and small stem screening), by allowing more large-diameter trees to remain, and by reducing the number of sapling-sized trees. (Four-inch diameter downed wood is identified within the downed wood volume factor.) Other parameters being equal, scenic beauty is greater early in the season than later for the area surveyed. Standardized beta coefficients suggest that the visual penetration factor contributes substantially to model prediction.

DISCUSSION

Several scenic beauty models are presented in this study: predictive models with standard and nonstandard parameters, study-based models, and principal components models. In none of the models does the coefficient of determination (R**2) exceed 0.52. While this is comparable to other SBE studies conducted under similar constraints, we suggest that model fitting can be improved by including as parameters other field measures hypothesized to be related to visual preferences.

The models developed for east Texas pine stands generally agree with studies of within-stand forest scenes in Massachusetts (Brush 1979), southwestern United States ponderosa pine stands (Brown and Daniel 1984), and North Carolina loblolly-shortleaf pine stands (Buhyoff et al. 1986). Overall, large-diameter trees contribute to visual preferences while smaller diameter trees detract from visual preferences. The models extend this hypothesis to include understory vegetation of southern pine and oak-pine stands of east Texas.

Models described in this report also may apply to other southern pine stands where conditions and the range of the parameters are similar. Unlike other scenic beauty studies that cite surrogate parameters such as stand age, total basal area, or average diameter of trees (e.g., Buhyoff et al. 1986, Vodak et al. 1985), models in this report employ direct measures of visually important parameters. In addition, these models take into account some of the variation over large areas that are not associated with stand age but that can substantially affect visual preferences.

Stand age is particularly poor as a surrogate of visually important understory vegetation structure in high-graded stands (stands where only the merchantable trees have been removed); in stands with crown gaps due to windthrow, insect and disease damage, or partial crown thinnings; and in truly uneven-aged stands. In such stands, the diameter class and age distribution of trees can be bimodal or skewed. These yield stand ages, average diameter, and basal area values that relate less to stand structure than would

TABLE 4. Correlation matrix for parameters in Table 3.[a]

	SMSTT	SMSTSWT	GCFLV	BALVSW	SAPT	LVACSW	BALVHW
SMSTT	1.00	0.95	0.89	0.68	−0.20	−0.24	0.23
SMSTSWT	1.00	0.82	0.73	−0.22	−0.23	−0.00	
GCFLV			1.00	0.71	−0.25	−0.26	0.31
BALVSW				1.00	−0.01	0.16	−0.09
SAPT					1.00	0.78	0.14
LVACSW						1.00	−0.22
BALVHW							1.00
PLHWT							
VSPN							
FTWG							
JDATE							
LONG							
DW4							
LGSTT							

[a] $P(|r| > 0.16) = 0.10$, $P(|r| > 0.20) = 0.05$, $P(|r| > 0.26) = 0.01$, $P(|r| > 0.39) = 0.001$.

occur in relatively undisturbed and even-aged stands. Forest inventory-based models that contain visual penetration or screening parameters are also more likely to be sensitive to multiuse perturbations in understory vegetation (e.g., structural changes that result from overgrazing by deer, from chemical brush control, prescribed burning, and occasional cattle grazing)—aspects of human-dominated pine forest ecosystems prevalent in east Texas and not uncommon elsewhere in southern pine stands.

In contrast to the positive relationship uncovered in our research between the amount of downed wood and scenic beauty evaluations, other studies have found a negative association (Brown and Daniel 1984, 1986, Vodak et al. 1985). In Brown and Daniel's study (1984), scenic beauty evaluations were found to be sensitive to estimates of downed wood less than ¼ in. diameter—more than the larger diameter downed wood estimates. Downed wood volume on east Texas plots are estimates derived from pieces 1 in. or more in diameter and in 1 ft or more in length; smaller diameter downed wood was not measured. Downed wood volume in the current study also averaged less than ⅒th of the amount reported in ponderosa pine stands in southwestern United States (Brown and Daniel 1984).

In Vodak et al. (1985), height above ground and percent cover of downed wood were used rather than volume estimates. For the east Texas plots, screening by above-ground downed wood is accounted for by screenometer measures, while downed wood volume is assessed separately. Most downed wood on the east Texas plots were not "visually predominant" as reported in Virginia oak-hickory stands (Vodak et al. 1985).

In the principal components analysis, 4-in. diameter downed wood density (DW4) is combined with downed wood volume (LDWV). Simple correlations suggest DW4 is significantly associated with stand age, tree basal area, stand size class, and average diameter of trees (r = 0.30, 0.29, 0.27, and 0.25, respectively). Therefore, this parameter actually may be a surrogate measure of stand development.

In order to reconcile our findings with those of others, we hypothesize that downed wood by itself does not detract from scenic beauty as much as whether associated dead leaves (generally present only in recently harvested stands) and their above-ground position in the scene limits visual penetration. The suggested association between downed wood and scenic

TABLE 4. Continued.

PLHWT	VSPN	FTWG	JDATE	LONG	DW4	LGSTT
0.15	0.10	−0.28	−0.05	−0.14	0.18	0.23
0.02	0.09	−0.24	−0.00	−0.10	0.15	0.16
0.21	0.06	−0.30	0.03	−0.19	0.31	0.43
−0.04	0.10	−0.26	0.03	0.05	0.14	0.15
0.00	−0.34	0.39	−0.16	−0.05	−0.07	−0.12
−0.18	−0.16	0.22	−0.11	0.16	−0.02	−0.20
0.71	−0.02	−0.12	−0.06	−0.21	0.16	0.34
1.00	0.04	−0.19	−0.12	−0.09	0.09	−0.01
	1.00	−0.93	−0.09	0.26	0.04	−0.00
		1.00	0.08	−0.21	−0.11	−0.05
			1.00	0.38	−0.05	0.16
				1.00	−0.09	−0.06
					1.00	0.16
						1.00

beauty is positive at low densities and then reaches an optimum beyond which downed wood density becomes negative. Small amounts of downed wood, as might occur with light cutting activity and tree fall gaps, can increase scenic beauty of developed, older stands by adding variety to the ground layer. With heavy cutting or a massive blowdown of trees, the density of downed wood (mainly as aboveground branches, twigs less than 1 in. diameter, and leaves) reduces the observer's view above ground, thereby decreasing visual penetration. Given the above hypothesis, we suggest estimation of downed wood volume 1 in. or greater in diameter in southern pine forest inventories is of secondary importance for the limited range of data examined in this study. Downed wood estimates from routine forest inventories may still be important and negatively related to forest scenic beauty if consideration is given to smaller diameter downed wood or greater downed wood volume or density than that found in this study.

The significance of Julian date and location parameters in east Texas may be a function of the plots selected, as plots were not chosen at random but selected to represent the range of forest management conditions, given the working schedule of survey crews. Probably Julian date and location represent unmeasured parameters that affect visual preferences (e.g., seasonal moisture and nutrient levels affecting the relative greenness and texture of foliage on trees, shrubs, and herbs over the course of the summer sampling period). An underlying mechanism may be a change in texture of the forest vegetation from exposure to the elements. Enough evidence is present to suggest that there are important differences in visual preferences within the summer season that should be accounted for in managing forests for scenic beauty. A random selection of locations for a range of time intervals and known seasonal moisture and nutrient levels would aid in testing this hypothesis.

IMPLICATIONS AND CONCLUSIONS

Within-stand scenic beauty in east Texas pine and oak-pine stands can be improved by increasing the number of sawtimber-sized trees, by removing understory foliage and twigs to increase visual penetration, and by reducing sapling-sized trees. Timber management activities that could accomplish

TABLE 5. Factor eigenvalues and loadings for parameters correlated with plot-level scenic beauty estimates

Factor number Name	1 Small sawtimber density	2 Sapling density	3 Poletimber density	4 Visual penetration	5 Late in the season	6 Downed wood volume	7 Large sawtimber density
Eigenvalue	7.92	3.75	2.33	2.17	1.67	1.35	1.03
Percent variation	31.69	15.01	9.32	8.69	6.69	5.41	4.11
				Factor Loadings			
Parameter			*(correlation coefficient × 100)*				
SMSTT	91*	−15	6	3	−12	7	11
SMSTSWT	91*	−17	−13	0	−10	3	5
BALVSW	88*	20	−13	15	0	1	−7
GCFLV	86*	−16	15	5	−5	18	30
BALV	81*	19	40*	13	−5	8	9
SVC	77*	−17	11	−3	12	20	33
SIZEC	74*	−19	12	−1	20	28	20
TRBOLE	60*	−17	46*	19	−10	1	1
AGE	55*	−16	29	−6	14	37*	44*
LVAC	−5	93*	18	−18	−12	−7	−2
LVACSW	−5	92*	−20	1	4	5	−17
SAPT	−12	92*	11	−22	−11	−8	4
SAPSWT	−12	92*	−19	−3	4	6	−11
AVGD	42*	−44*	−10	27	10	36*	−7
BALVHW	9	3	90*	−1	−8	12	27
PLHWT	9	−6	87*	3	−12	10	−12
VSPN	1	−17	−3	96*	−2	4	−2
FTWG	−22	21	−13	−92*	4	−4	1
JDATE	5	−13	1	−12	84*	−6	4
LONG	−3	12	−4	34	69*	−8	−33
LAT	10	7	25	8	−71*	−2	−21
DW4	10	1	2	3	−9	84*	7
LDWV	27	0	22	3	−3	80*	8
SITEC	26	−8	−7	−8	−15	−1	72*
LGSTT	18	−6	16	6	22	14	72*

* Loadings with correlations ($r \times 100$) 36 or greater.

these objectives include periodic thinnings, use of prescribed fires, well-planned seed-tree and selective harvests that retain some of the larger trees in established stands, and reducing the frequency of clearcuts and other actions that temporarily increase dense vegetative growth.

Relatively lengthy harvest rotations and understory clearings may increase scenic beauty for east Texas pine and oak-pine stands. Concurrence with other studies in different forest types and parts of the United States suggests that these associations can be applied to other areas where the range of the parameters are the same. In forest stands subject to public view (e.g., along roadsides), longer rotations that retain sawtimber-sized trees may provide public benefits. Because species composition (hardwood vs. softwood) does not seem to detract from scenic beauty, establishment and retention of long-rotation pine plantations may benefit scenic beauty during the summer season if compatible with other forest uses. Since foliage, twig, and small stem screening and density of sapling-sized trees appear to detract

TABLE 6. Models that predict scenic beauty from principal components.

Factor number	Description and regression (R**2, R**2-adj, PRESS-R**2)	Coefficient	Beta	$P > \|t\|$
(1) With standard parameters (0.21, 0.19. 0.17).				
1	Small sawtimber density	10.53	0.34	0.0003
2	Sapling density	−9.13	−0.30	0.0014
	(Constant)	−1.30	0.00	0.6381
(2) With standard and nonstandard parameters (0.36, 0.33, 0.28).				
4	Visual penetration	11.40	0.37	0.0001
1	Small sawtimber density	9.21	0.30	0.0004
2	Sapling density	−7.68	−0.25	0.0031
6	Downed wood volume	6.28	0.21	0.0148
3	Poletimber density	5.23	0.17	0.0412
	(Constant)	−1.30	0.00	0.6054
(3) With standard and study-based parameters (0.33, 0.31, 0.28)				
1	Small sawtimber density	10.98	0.36	0.0001
6	Late in the season	−10.03	−0.33	0.0002
2	Sapling density	−9.54	−0.31	0.0003
	(Constant)	−1.30	0.00	0.6100
(4) With standard, nonstandard, and study-based parameters (0.52, 0.49, 0.45).				
4	Visual penetration	11.64	0.38	0.0001
5	Late in the season	−11.30	−0.37	0.0001
1	Small sawtimber density	9.15	0.30	0.0001
2	Sapling density	−8.16	−0.27	0.0004
6	Downed wood volume	6.93	0.23	0.0022
7	Large sawtimber density	5.40	0.18	0.0160
	(Constant)	−1.30	0.00	0.5525

from scenic beauty, limiting understory growth through practices such as periodic low-intensity prescribed fires, occasional cattle grazing, and removal of tree branches below 6 ft may increase scenic beauty in poletimber and sawtimber stands.

The positive association between downed wood and scenic beauty should be viewed with caution, because these results differ from those reported elsewhere. Size and condition of downed wood observed in our study may be different than that observed in other studies. At the very least, however, results suggest that there is a level or condition of downed wood volume that does not detract from scenic beauty of within-stand forest scenes.

The potential value of regional scenic beauty modeling and monitoring depends, to a large extent, on the kinds of measurements routinely collected in extensive sampling efforts, such as FIA forest surveys. Incorporation into forest surveys of readily quantified, repeatable parameter estimates relevant to visual preferences may help alleviate the uncertainty in relying solely on intercorrelated timber-oriented inventory parameters as surrogates for scenic beauty. Addition of nonstandard but visually important parameters to extensive forest sampling efforts may also contribute to understanding of variability in scenic beauty among different forest-stand types and regions. Assessing the amount of herbaceous vegetation, a promising measure positively correlated with scenic beauty (Brown and Daniel 1986), needs careful study for use with extensive sample surveys. Parameter estimates involving judgment, such as understory foliar cover (Popham and Baker 1987), may require use of scaling devices and knowledge of observer and seasonal variation if reliable estimates and models are to be obtained, and if patterns over time and across regions are to be determined objectively.

Within-season variation was not a planned aspect of the study. Nevertheless, the importance of time-of-year in visual preference studies is apparent. The capability for forest stands to change both within and among seasons may be an important parameter in assessing visual preferences for a given forest type, and in managing stands for scenic beauty. A pine stand with a hardwood understory may elicit different responses from viewers in the course of a year than a well-managed pine stand that has no hardwood understory. Such differences may not be apparent for pictures taken in the summer, as in our examination, but would be obvious for pictures taken in other seasons. Even within the summer, subtle differences are likely. Macro-scale scenic beauty assessments, as with statewide or regional forest inventories, may require additional data on scenic beauty estimates averaged over a year before scenic beauty can be fully compared with alternative forest management outputs.

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